

## PATENT ABSTRACTS OF JAPAN

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## (54) CALIBRATING METHOD FOR NETWORK ANALYZER

## (57)Abstract:

PROBLEM TO BE SOLVED: To eliminate a measurement error, increase the utilization value, and improve the technical value by making calibration via calculation when the value of the reflection coefficient of a load element is known even if it is not ideal nonreflection.

SOLUTION: A calibration kit having a known reflection coefficient is used, and three kinds of elements including an open element, a short element, and a load element are prepared. The reflection coefficients of the elements, i.e., the reflection coefficient Aopen of the open element, the reflection coefficient Ashort of the short element, and the reflection coefficient Aload of the load element, are stored in the memory section of a network analyzer. The open element is connected to the input/output terminal of the network analyzer, a signal is sent from a signal source, and a response signal is measured at a reception section. Measured values of S11m are stored in the memory section as f(open), f(short), and f(load). Ed, Es, Er are obtained by an arithmetic section according to the first equation with the reflection coefficients Aopen, Ashort, Aload and measured values (f), and calibration is made.

校正用のOpen素子の反射係数: Aopen=1/2  
Short素子の反射係数: Ashort=-1/2  
Load素子の反射係数: Aload=ρ  
を代入する

open素子を接続したときのS11mの測定値: f(open)  
short素子を接続したときのS11mの測定値: f(short)  
load素子を接続したときのS11mの測定値: f(load)  
を代入する

Aopen, Ashort, Aload及びf(open), f(short), f(load)  
を用いて、式(1)の第一式に代入して算出するEd, Es, Erを  
求める。

(第一式)

$$\begin{bmatrix} E_d \\ E_r - E_d E_s \\ E_s \end{bmatrix} = \begin{bmatrix} A_{open} & A_{open} f(open) \\ A_{short} & A_{short} f(short) \\ A_{load} & A_{load} f(load) \end{bmatrix} \begin{bmatrix} f(open) \\ f(short) \\ f(load) \end{bmatrix}$$

## LEGAL STATUS

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CLAIMS

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## [Claim(s)]

[Claim 1] In the calibration of one port of a network analyzer The proofreading kit which has a known reflection coefficient is used, and they are the reflection coefficient Aopen of an opening component, and the reflection coefficient Ashort of a short component. Memory of the reflection coefficient Aload of a load component is carried out to the storage section of a network analyzer. S11m the measured value f (open) and the short component which connected with the terminal and measured the opening component are connected to a terminal. Memory of the S11m measured value f (load) which connected with the terminal and measured S11m the measured value f (short) and the load component which were measured is carried out to the storage section of a network analyzer. Using the above-mentioned reflection coefficients Aopen, Ashort, and Aload and the above-mentioned measured value f (open), f (short), and f (load), according to the first number type of several 1, it calculates by operation part, and is [Equation 1].

$$\begin{bmatrix} E_d \\ E_r - E_d \cdot E_s \\ E_s \end{bmatrix} = \begin{bmatrix} 1 & A_{open} & A_{open} \cdot f(open) \\ 1 & A_{short} & A_{short} \cdot f(short) \\ 1 & A_{load} & A_{load} \cdot f(load) \end{bmatrix}^{-1} \begin{bmatrix} f(open) \\ f(short) \\ f(load) \end{bmatrix}$$

--- (第一数式)

The calibration approach of the network analyzer characterized by performing a calibration in quest of the error factors Ed, Es, and Er.

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DETAILED DESCRIPTION

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## [Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the calibration approach of a network analyzer (Network Analyzer).

[0002]

[Description of the Prior Art] First, general explanation about a network analyzer is given. A network analyzer measures the frequency characteristics of the RF of the amounts of many [ electric ] of a network, electronic parts, and an electronic ingredient. It is the measuring instrument which is made to generate the very small electrical signal of a sine wave, gives DUT (device under test), measures the reflection property and transmission characteristic, i.e., a reply signal, by the S parameter, and is analyzed. A reply signal is vector quantity which generally has the information on the amplitude and a phase, and is complex. Then, the measuring instrument which analyzes the vector quantity of this amplitude and a phase is also called vector network analyzer.

[0003] Since the internal configuration of a network analyzer is common knowledge, it is omitted, and it shows a basic configuration with a built-in S parameter test set to drawing 3. One is a network analyzer with a built-in S parameter test set among drawing, and, generally [ DUT and 3 ] 2 uses a sweep oscillator in the source of a signal. 4 is a receive section A, it is changed into low frequency in response to an input signal with a mixer, carries out analog-to-digital conversion (A/D), performs rectangular detection, and is measured as one complex in quest of the real number value R and the imaginary value X. 5 measures the sending signal from the source 3 of a signal in a receive section R. 6 is a receive section B. These three receive sections synchronize so that the signal of the frequency outputted from the source 3 of a signal may be detected.

[0004] 7 is the power splitter which separates the signal from the source 3 of a signal, one signal was given to DUT2 through the RF switch 8, and the signal of another side is given to the receive section R5. RF switch of 8 is a terminal 101 about the output signal from the source 3 of a signal. In outputting from a port 1 \*\*\*\*, it is a terminal 102. It is for outputting from a port 2. 91 92 Terminal 101 Or terminal 102 from — it is the bridge or directional coupler which takes out a reply signal. The S parameter of DUT2 is measured with this network analyzer 1 with a built-in S parameter test set.

[0005] An S parameter is briefly explained using drawing 4. If a test frequency becomes high and it becomes impossible for system of measurement to treat in concentrated constant, like drawing 4 (A), as a parameter of a network, an incident wave, a reflected wave, and a carrier wave will be defined as a variable, and will be measured. The parameter of this defined network is an S parameter. For example, as shown in drawing 4 (B), a signal  $a_1$  is given to the port 1 of DUT2 from the source 3 of a signal, and a port 2 presupposes that termination is carried out with the characteristic impedance  $Z_0$ .  $S_{11}$  at this time sets to the ratio of the incident wave  $a_1$  in a port 1, and a reflected wave  $b_1$ , and  $S_{11}=b_1/a_1$ , is defined, and is called the reflection coefficient in a port 1.  $S_{21}$  sets to the ratio of the carrier wave  $b_2$  from a port 1 to a port 2, and the incident wave  $a_1$  of a port 1, and  $S_{21}=b_2/a_1$ , is defined, and is called the transmission coefficient from a port 1 to a port 2, or a transmission coefficient.  $S_{22}$  and  $S_{21}$  give a signal  $a_2$  from a port 2, are what carried out termination of the port 1 and measured it with the characteristic impedance  $Z_0$ , and are defined as  $S_{22}=b_2/a_2$  and  $S_{12}=b_1/a_2$ .

[0006] Drawing 4 (C) expresses this relational expression by the matrix. Drawing 4 (D) is explanation of the contents of the S parameter. A network analyzer 1 converts and displays the S parameter obtained in this way on various properties of DUT2. For example, the LOGMAG display which carries out dB conversion and displays the amplitude, the PHASE display which displays a phase, and group delay A DELAY display and standing-wave ratio An SWR display and the Smith chart A SMITH display and Polar chart It is a POLAR display etc. By the way, when it is going to measure the reflection property of DUT2 with a network analyzer 1, true value of DUT2

cannot be measured directly according to the error of system of measurement. Then, the cause of this error can be known and measured value can be amended by considering a suitable model.

[0007] Next, measurement of the conventional network analyzer related to this invention is explained below using drawing 5. Drawing 5 (A) is system of measurement which measures the reflection property of DUT2 with a network analyzer. The signal from the source 3 of a signal is given to DUT2, the reflected wave is taken out on a bridge 9, and it measures by receive section A4.

[0008] The measurement error factor in this case is shown in drawing 5 (B). That is, it is the error which mainly originates in the directivity, frequency tracking, and source match of system of measurement. Although the error of directivity must separate the incidence signal and the reflective signal from DUT2 which go to DUT2 on a bridge 9, it is included in measured-value S11m, the leakage, i.e., the leakage signal, from the forward direction, and it is an error by this. The error by frequency tracking is an error of the frequency response of system of measurement. With the error by the source match, when adjustment of the impedance by the side of the source of a signal and the impedance of a gaging-system system cannot be taken, the signal reflected by DUT2 reflects again by the source 3 side of a signal, and returns and re-reflects in DUT2. It is an error by this re-reflection.

[0009] The disturbance models of reflection property measurement of one port including these become like drawing 5 (C). S11m is [ a true value, and Ed, Er and Es of measured value and S11a ] error factors here.

Although explanation omits this disturbance model, if it solves by signal flow graph and asks for S11m, it can express by drawing 5 (D). If it deforms and asks for true-value S11a, it can express by drawing 5 (E). Since an unknown is three, Ed, Er, and Es, if the standard device whose property is known three is used, it can ask for these unknowns here.

[0010] namely, opening (release) — if short (short circuit) and three conditions of loading (standard load Zo) are built, the value of the S11m measured value f (short), f (open), and f (load) at each time is recorded and it calculates using the value, it can ask for true reflection coefficient S11a of DUT2. This is called calibration. That is, the calibration measures beforehand the error which system of measurement has, and is removing the effect by the operation.

[0011] A proofreading kit is to build [ opening and ] the condition of short and loading. An example is shown in drawing 6. Drawing 6 (A) is an external view, 11 is a connector and 12 is a body. Although the terminal 13 is wide opened with the opening component, since stray capacity C etc. exists, drawing 6 (B) considers amendment of a phase, and its reflection coefficient Aopen is (1xejalpha). Drawing 6 (C) A terminal 14 is short-circuited with a short component, phase correction is considered, and it is a reflection coefficient Ashort. It is (-1xejbeta). Drawing 6 (D) was carried out with the load component, termination of the terminal 15 was carried out with the characteristic impedance Zo, and the reflection coefficient is assumed to be 0. Generally a characteristic impedance Zo is 50ohmYA75ohm in many cases.

[0012] The conventional calibration approach is shown in drawing 2. Reflection coefficient Aopen= of the opening component of the introduction proofreading kit (1xejalpha), Memory of reflection coefficient Ashort = (-1xejbeta) of a short component is carried out to the storage section of a network analyzer 1. Next, it connects with terminal 10i, assuming a load component to be areflaxia, reflection coefficient =0 [ i.e., ], and the reply signal is measured by receive section A4. The S11m measured value f (load) is calculated from the formula of drawing 5 (D), and serves as f(load) =S11 m=Ed+[Er and 0/(1-Es, 0)] =Ed. that is, measured-value f(load) =Ed it is — Ed can be found.

[0013] Next, an opening component is connected to terminal 10i, and memory is carried out in quest of the measured value f (open), A short component is connected and memory is carried out in quest of the measured value f (short). It is here and is f(open) =f(load)+ [Er-Aopen/(1-Es-Aopen)].  
f(short) =f(load)+ [Er-Ashort/(1-Es-Ashort)]

It comes out, and since it is, the second formula is obtained by allying these two formulas. If f (open) and f (short) of measured value can be found, it is Aopen and Ashort of a reflection coefficient. It uses, and calculates according to the second formula of several 2, and Es and Er are calculated.

[0014]

[Equation 2]

$$\begin{bmatrix} E_s \\ E_r \end{bmatrix} = \begin{bmatrix} A_{short} \cdot [f(\text{short}) - f(\text{load})] \\ A_{open} \cdot [f(\text{open}) - f(\text{load})] \end{bmatrix}^{-1} \begin{bmatrix} f(\text{short}) - f(\text{load}) \\ f(\text{open}) - f(\text{load}) \end{bmatrix}$$

--- (第二数式)

[0015] The flow chart of the conventional calibration approach mentioned above to drawing 2 is shown. Aopen and Ashort of a reflection coefficient of the opening component of a proofreading kit, and a short component

Memory is carried out. If it connects with a terminal, assuming the reflection coefficient of a load component to be 0, a signal is given from the source of a signal and the reply signal is measured, the measured value will serve as  $S_{11m} = f(\text{load}) = E_d$ , and  $E_d$  can be found. Memory of the measured value  $f(\text{open})$  and  $f(\text{short})$  is measured and carried out similarly. According to the second formula, it calculates using these  $A_{\text{open}}(s)$  and  $A_{\text{short}}(s)$ , and  $f(\text{open})$  and  $f(\text{short})$ ,  $E_s$  and  $E_r$  are calculated, and a calibration is performed.

[0016]

[Problem(s) to be Solved by the Invention] It was performed by the conventional calibration approach, having assumed the load component of a proofreading kit to be reflection coefficient  $=0$ . Then, the force was directed towards development of a nonreflective load component. That is, although a hand only has assuming that a load component is ideal and it was referred to as reflection coefficient  $=0$ , there is some reflection actually. Therefore, the part which this load component does not have became an error in a calibration, and was producing some measurement error.

[0017] This invention does not assume the reflection coefficient of a load component to be 0, but is reflection coefficient  $=\rho$ . It considers as a known value and aims at offering the approach of a new calibration of acquiring the error factor which does not produce a measurement error from this.

[0018]

[Means for Solving the Problem] In order to attain the above-mentioned purpose, this invention uses the proofreading kit which has a known reflection coefficient. Three kinds of components, an opening component, a short component, and a load component, are prepared for the proofreading kit. The reflection coefficient of each of this component, i.e., the reflection coefficient  $A_{\text{open}}$  of an opening component and the reflection coefficient  $A_{\text{short}}$  of a short component, Memory of the reflection coefficient  $A_{\text{load}}$  of a load component is carried out to the storage section of a network analyzer.

[0019] Next, an opening component is connected to the input/output terminal of a network analyzer, from the source of a signal, a signal is measured by delivery and the reply signal is measured in receive section A4 or receive section B6. The measured  $S_{11m}$  measured value is set to  $f(\text{open})$ .  $S_{11m}$  measured value which connected with the terminal and measured the short component is set to  $f(\text{short})$ .  $S_{11m}$  measured value which connected with the terminal and measured the load component is set to  $f(\text{load})$ . Memory also of this measured  $f(\text{open})$ , and  $f(\text{short})$  and  $f(\text{load})$  is carried out to the storage section of a network analyzer.

[0020] Next, according to the first number type of several 1, a calibration is performed in quest of  $E_d$ ,  $E_s$ , and  $E_r$  using the above-mentioned reflection coefficients  $A_{\text{open}}$ ,  $A_{\text{short}}$ , and  $A_{\text{load}}$  and the above-mentioned measured value  $f(\text{open})$ ,  $f(\text{short})$ , and  $f(\text{load})$  by operation part.

[0021]

[Equation 3]

$$\begin{bmatrix} E_d \\ E_r - E_d - E_s \\ E_s \end{bmatrix} = \begin{bmatrix} 1 & A_{\text{open}} & A_{\text{open}} \cdot f(\text{open}) \\ 1 & A_{\text{short}} & A_{\text{short}} \cdot f(\text{short}) \\ 1 & A_{\text{load}} & A_{\text{load}} \cdot f(\text{load}) \end{bmatrix}^{-1} \begin{bmatrix} f(\text{open}) \\ f(\text{short}) \\ f(\text{load}) \end{bmatrix}$$

--- (第一数式)

[0022]

[Embodiment of the Invention] The gestalt of implementation of invention is explained with reference to a drawing based on an example. The flow chart of one example of the calibration approach of this invention is shown in drawing 1. The reflection coefficient of three components of a proofreading kit is  $A_{\text{load}}=0$  with  $A_{\text{short}}=-1$  and a load component in  $A_{\text{open}}=1$  and a short component by the opening component ideally. However, it is not actually ideal and there is some error. Then, correction value  $\alpha$ ,  $\beta$ , and  $\rho$  is clarified by measuring correctly in advance, calculating theoretically, or purchasing a thing [finishing / amendment]. A reflection coefficient is  $A_{\text{load}}=\rho$  with  $A_{\text{short}}=(-1 \times \beta)$  and a load component in  $A_{\text{open}}=(1 \times \alpha)$  and a short component by the opening component. Memory of this reflection coefficient is carried out to the storage section of a network analyzer.

[0023] Next, these three components are connected to input/output terminal 10i of drawing 5 (A) by turns, from the source 3 of a signal, a signal is given and the reply signal is measured by receive section A4. Memory is carried out to the storage section, setting  $S_{11m}$  measured value when connecting an opening component to  $f(\text{open})$ , and using  $S_{11m}$  measured value when connecting  $f(\text{short})$  and a load component for the  $S_{11m}$  measured value when connecting a short component as  $f(\text{load})$ .

[0024] by the way, the formula of drawing 5 (D) —  $S_{11m} = E_d + \{E_r - S_{11a} / (1 - E_s - S_{11a})\}$  it is — since — if this formula is transformed —  $S_{11m} = E_d + S_{11a}(E_r - E_d - E_s) + S_{11a} - S_{11m} - E_s$  It becomes. Here, if a reflection coefficient is substituted for  $S_{11a}$  for the measured value mentioned above to  $S_{11m}$ , the following three

formulas will be obtained.

$f(\text{open}) = E_d + A_{\text{open}}(E_r - E_d - E_s) + A_{\text{open}} - f(\text{open})$ ,  $E_{sf}(\text{short}) = E_d + A_{\text{short}}(E_r - E_d - E_s) + A_{\text{short}} - f(\text{short})$  and  $E_{sf}(\text{load}) = E_d + A_{\text{load}}(E_r - E_d - E_s) + A_{\text{load}} - f(\text{load})$ , and  $E_s$  — the first number type of several 1 indicated these three formulas by the matrix. These three formulas can be calculated by operation part, and  $E_d$ ,  $E_s$ , and  $E_r$  of an unknown can be calculated. That is, a calibration can be carried out, without assuming that it is  $A_{\text{load}}=0$ .

[0025]

[Effect of the Invention] it explained to the detail above — as — this invention — the reflection coefficient of a load component (an alias name load — standard) — 0 — that is, ideal — even if not nonreflective, when that value was known, the calibration became possible by the operation. Therefore, production of a load component became easy, the factor of a measurement error was lost, and the utility value of a network analyzer increased. Technical worth of this invention is size.

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[Translation done.]

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] It is the flow chart of one example of the calibration approach of this invention.

[Drawing 2] It is the flow chart of the conventional calibration approach.

[Drawing 3] It is the block diagram of an example of a network analyzer with a built-in S parameter test set.

[Drawing 4] It is the explanatory view of an S parameter. For (A), the explanatory view of an incident wave, a reflected wave, and a carrier wave and (B) are [ the relational expression of an S parameter and (D of the explanatory view of each S parameter and (C)) ] explanation of each S parameter.

[Drawing 5] It is the explanatory view of 1 port reflection property measurement. For a block diagram and (B), the explanatory view of a measurement error and (C) are [ (A) / measured-value S11m relational expression and (E of a disturbance model Fig. and (D)) ] the relational expression of true-value S11a.

[Drawing 6] It is the explanatory view of a proofreading kit. For (A), an external view and (B) are [ a short component and (D of an opening component and (C)) ] load components.

[Description of Notations]

1 Network Analyzer with a Built-in S Parameter Test Set

2 DUT (Device under Test)

3 Source of Signal

4 Receive Section A

5 Receive Section R

6 Receive Section B

7 Power Splitter

8 RF Switch

9i, 91, 92 A bridge or directional coupler

10i, 101, 102 Terminal

11 Connector

12 Body

13 Opening Component Terminal

14 Short Component Terminal

15 Load Component Terminal

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## DRAWINGS

## [Drawing 1]

校正キットのopen素子の反射係数 ;  $A_{open}=1 \times e^{j\alpha}$   
 short素子の反射係数 ;  $A_{short}=-1 \times e^{j\beta}$   
 load素子の反射係数 ;  $A_{load}=\rho$   
 をメモリする。

open素子を接続したときのS11mの測定値 ;  $f(open)$   
 short素子を接続したときのS11mの測定値 ;  $f(short)$   
 load素子を接続したときのS11mの測定値 ;  $f(load)$   
 をメモリする。

$A_{open}$ ,  $A_{short}$ ,  $A_{load}$  及び  $f(open)$ ,  $f(short)$ ,  $f(load)$   
 を用いて、次式の第一数式に従って演算し、 $E_d$ ,  $E_s$ ,  $E_r$  を  
 求める。

(第一数式)

$$\begin{bmatrix} E_d \\ E_r - E_d - E_s \\ E_s \end{bmatrix} = \begin{bmatrix} 1 & A_{open} & A_{open} \cdot f(open) \\ 1 & A_{short} & A_{short} \cdot f(short) \\ 1 & A_{load} & A_{load} \cdot f(load) \end{bmatrix}^{-1} \begin{bmatrix} f(open) \\ f(short) \\ f(load) \end{bmatrix}$$

## [Drawing 2]

校正キットのopen素子の反射係数 ;  $A_{open}=1 \times e^{j\alpha}$   
 short素子の反射係数 ;  $A_{short}=-1 \times e^{j\beta}$   
 をメモリする。

校正キットのload素子の反射係数を0と仮定して接続し、  
 応答信号の測定値は  $S11m=f(load)=E_d$  となり、 $E_d$  が求ま  
 る。

open素子を接続したときのS11mの測定値 ;  $f(open)$   
 short素子を接続したときのS11mの測定値 ;  $f(short)$   
 をメモリする。

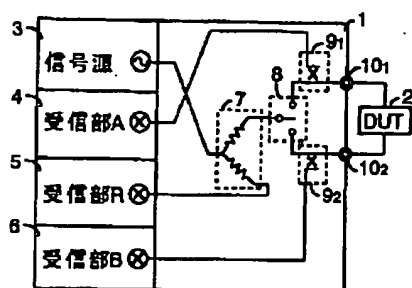
$A_{open}$ ,  $A_{short}$ ,  $f(open)$ ,  $f(short)$  を用いて、次式の第二数  
 式に従って演算し、 $E_s$ ,  $E_r$  を求める。

(第二数式)

$$\begin{bmatrix} E_s \\ E_r \end{bmatrix} = \begin{bmatrix} A_{short} \cdot [f(short) - f(load)] & A_{short} \\ A_{open} \cdot [f(open) - f(load)] & A_{open} \end{bmatrix}^{-1} \begin{bmatrix} f(short) - f(load) \\ f(open) - f(load) \end{bmatrix}$$

## [Drawing 3]



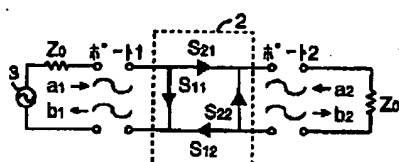


[Drawing 4]

(A)



(B)



(C)

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

(D)

S<sub>11</sub>: 出力側を特性インピーダンスZ<sub>0</sub>で終端したときの  
入力反射係数

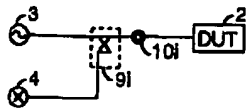
S<sub>21</sub>: 出力側を特性インピーダンスZ<sub>0</sub>で終端したときの  
順方向伝送係数

S<sub>12</sub>: 入力側を特性インピーダンスZ<sub>0</sub>で終端したときの  
逆方向伝送係数

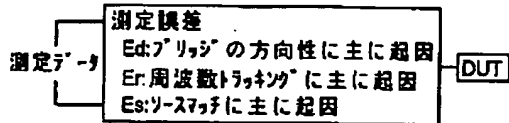
S<sub>22</sub>: 入力側を特性インピーダンスZ<sub>0</sub>で終端したときの  
出力側の反射係数

[Drawing 5]

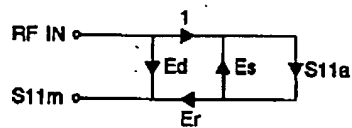
(A)



(B)



(C)



(D)

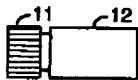
$$S_{11m} = E_d + \frac{E_r \cdot S_{11a}}{1 - E_s \cdot S_{11a}}$$

(E)

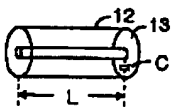
$$S_{11a} = \frac{S_{11m} - E_d}{E_s(S_{11m} - E_d) + E_r}$$

## [Drawing 6]

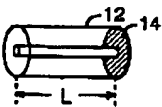
(A)



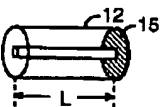
(B)



(C)



(D)



[Translation done.]